

The APS Real-Time Feedback System

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BNL 8/12/2010

Outline

- RTFB
- Orbit Control
- APS Upgrade and RTFB

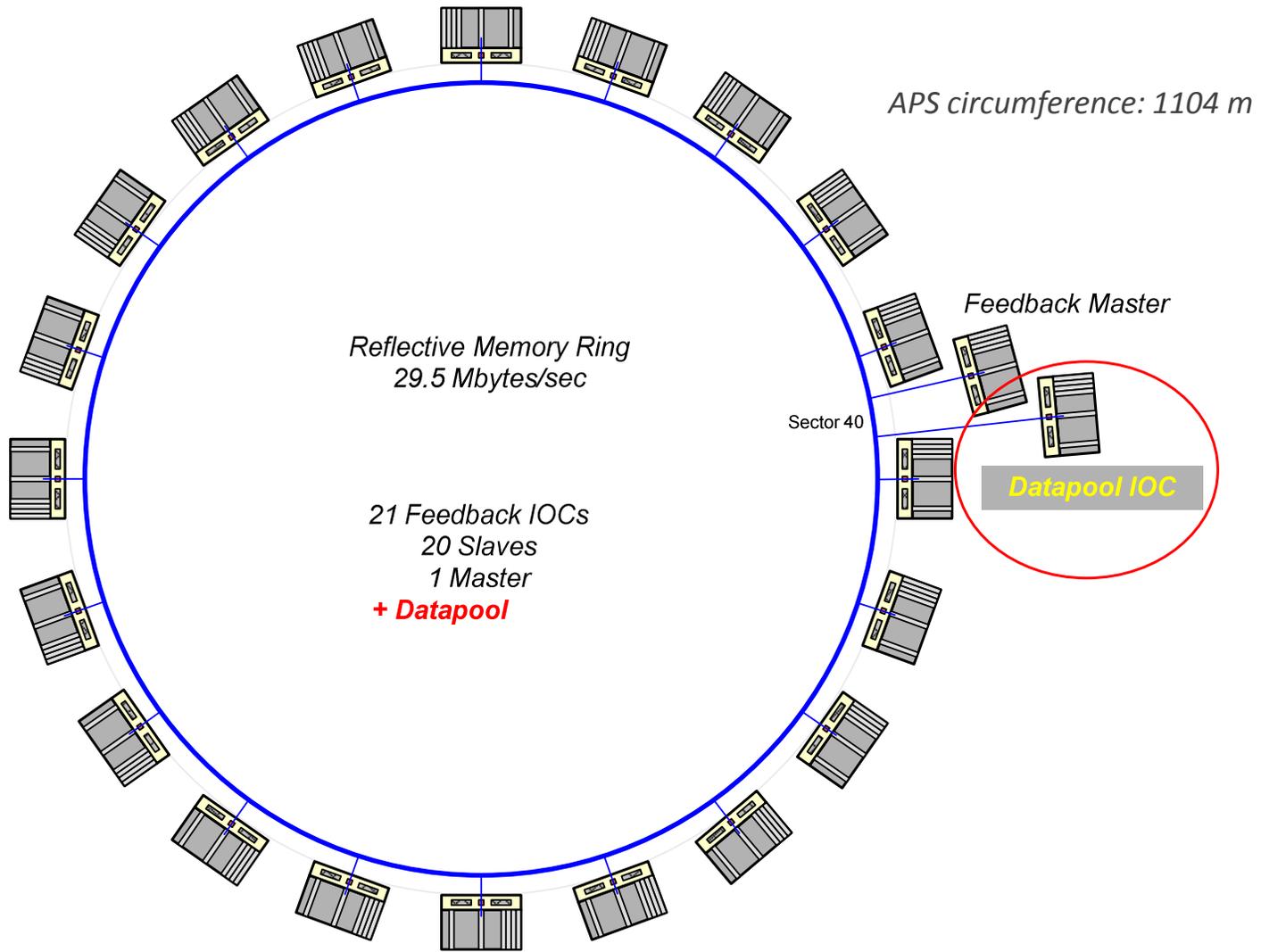


Transverse orbit feedback at APS

- Three types of transverse orbit feedback:
 - “DC” orbit control
 - Runs in the Datapool IOC (iocsbpmddp) connected to RTFB Reflective Memory Loop
 - Can use all correctors and bpms
 - “Real-Time” Feedback consists of 21 crates (1 master and 20 slaves)
 - Uses 160 bpms and 38 “Fast” correctors
 - Fast Correctors are mounted on stainless steel vacuum chambers
 - » “Slow” correctors are mounted on aluminum vacuum chambers
 - “AC” coupled; i.e, does not correct down to DC
 - Transverse Bunch-to-Bunch feedback (“P0 feedback”)
 - Corrects a transverse instability at large bunch current



RTFB Overview



Real-Time Feedback System Functions/Features

- Implements Feedback to reduce “Fast” orbit motion
- Provides data acquisition and processing for narrow-band BPMs (Bergoz) and X-ray BPMs
- Can drive all 640 SR correctors
 - For Orbit control
- Computes RMS beam motion from P2 or P0 bpms
 - P0 (ID chamber mounted BPMs typically used)
- Provides Beam diagnostic features:
 - DSP Scope
 - 40 channels
 - Captures time records at feedback sample rate of any feedback system data
 - AC Voltmeter
 - Performs Fast FFT at a single frequency on 360 RF BPMs
 - Corrector Error/Drive Stats
- Feed-Forward to correct for Septum Injection Transients
- Open loops at settable corrector drive limit



Real-Time Feedback System Functions (Cont.)

- Provides Feedback System Diagnostics
 - DSP Heartbeats
 - Reflective Memory Status
 - Dynamic Reflective Memory Testing

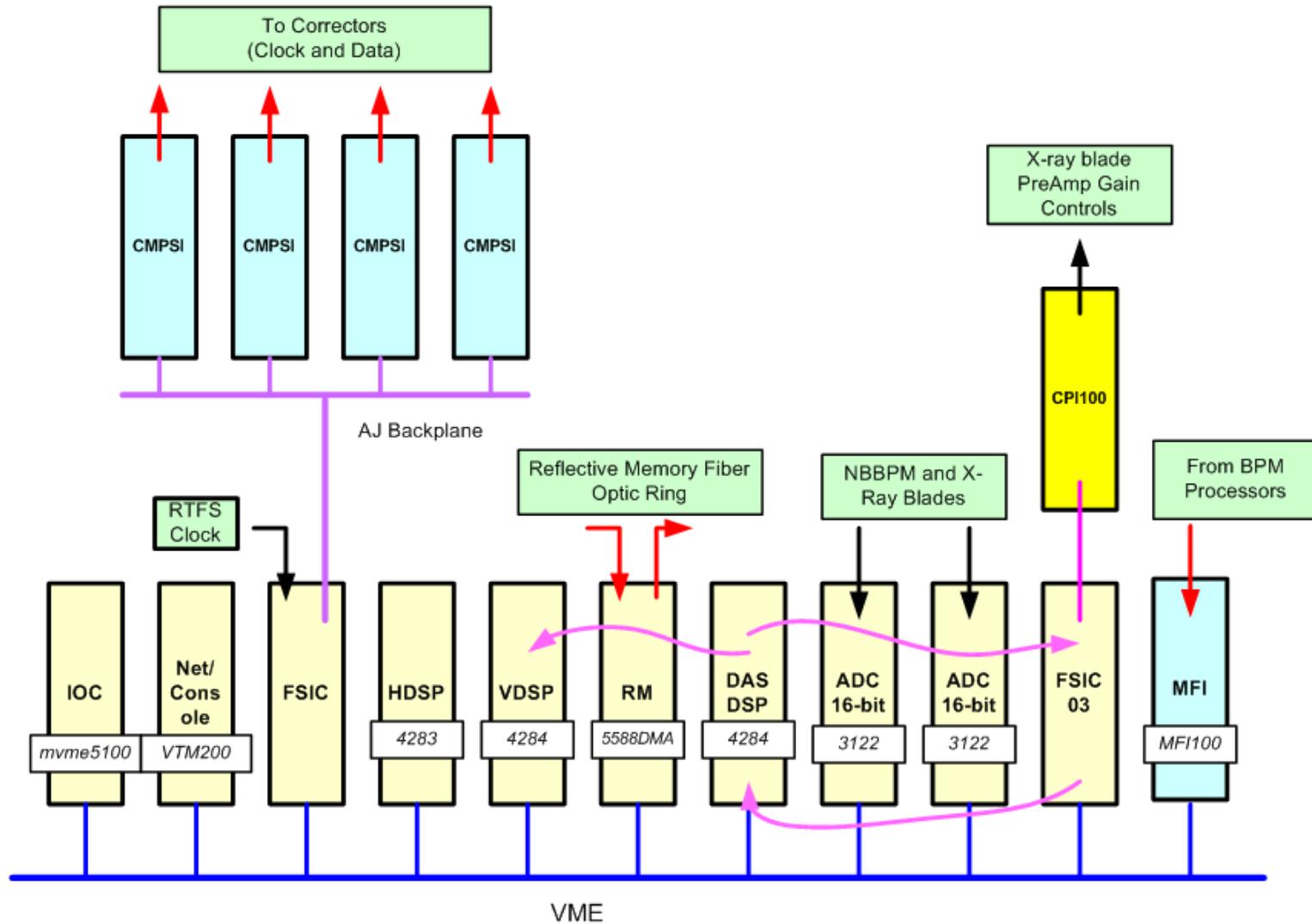


RTFB Facts

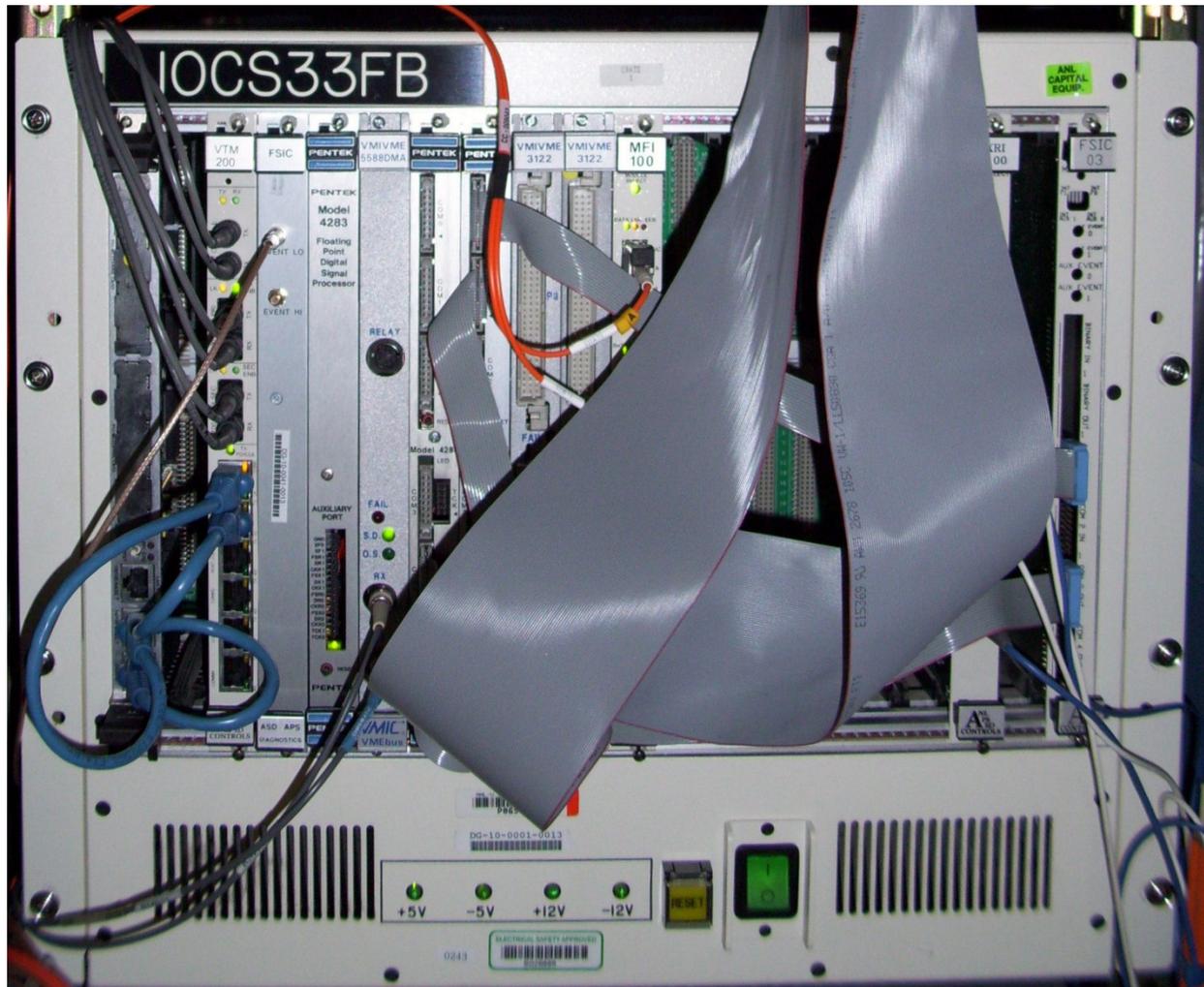
- The fast feedback system consists of 21 IOCs
 - 20 “Slave Crates (iocs1fb, iocs3fb iocs39fb)
 - 1 Master Crate (iocs40fb)
- The correction algorithm uses 160 BPMs and 38 correctors per axis
 - Correctors used are mounted on stainless steel vacuum chambers – A:H3s and A:V3s
- The Horizontal and Vertical planes operate at the same sampling rate but are independent calculations. (Separate DSP for each plane (HDSP, VDSP))
- Each feedback slave crate handles a double sector with 2 horizontal and 2 vertical correctors.
- The sampling frequency (iteration rate) is 1.534 kHz (actually a submultiple of the storage-ring revolution frequency.)
- BPMs Available to RTFB (per axis)
 - 280 RF Monopulse
 - 150 RF Narrowband
 - 70 ID x-ray
 - 70 BM x-ray (y-axis Only)



RTFB VME Node



RTFB IOC



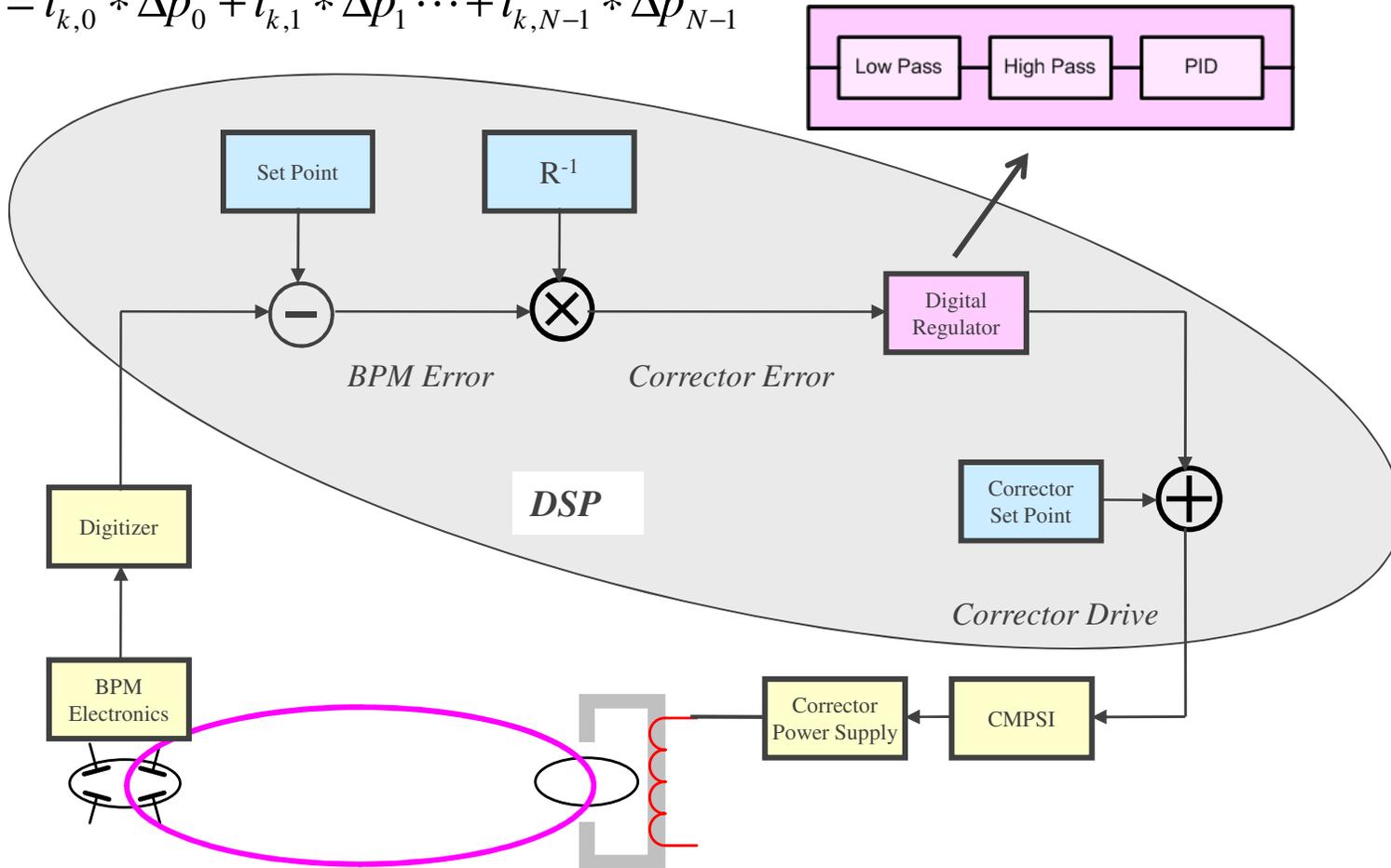
APS Real-Time Feedback System: BNL 8/12/2010, F. Lenkszus



RTFB

$$\begin{bmatrix} \Delta C_0 \\ \Delta C_1 \\ \vdots \\ \Delta C_{M-1} \end{bmatrix} = \begin{bmatrix} i_{0,0} i_{0,1} \cdots i_{0,N-1} \\ i_{1,0} i_{1,1} \cdots i_{1,N-1} \\ \vdots \\ i_{M-1,0} i_{M-1,1} \cdots i_{M-1,N-1} \end{bmatrix} \times \begin{bmatrix} \Delta p_0 \\ \Delta p_1 \\ \vdots \\ \Delta p_{N-1} \end{bmatrix}$$

$$\Delta C_k = i_{k,0} * \Delta p_0 + i_{k,1} * \Delta p_1 \cdots + i_{k,N-1} * \Delta p_{N-1}$$



Reflective Memory

- Also known as Replicated Memory
- Each participant in the reflective memory network has a reflective memory module.
- Each module can be written and read as simple memory
- **Property:**
 - Anything written to a location in one reflective memory module appears (after a loop transit time) in the same location in all attached modules.
 - Transfer rate 29.5 Mbytes/second
- All Nodes see the same memory image
- Designed for Real-time Performance – Latency is minimized

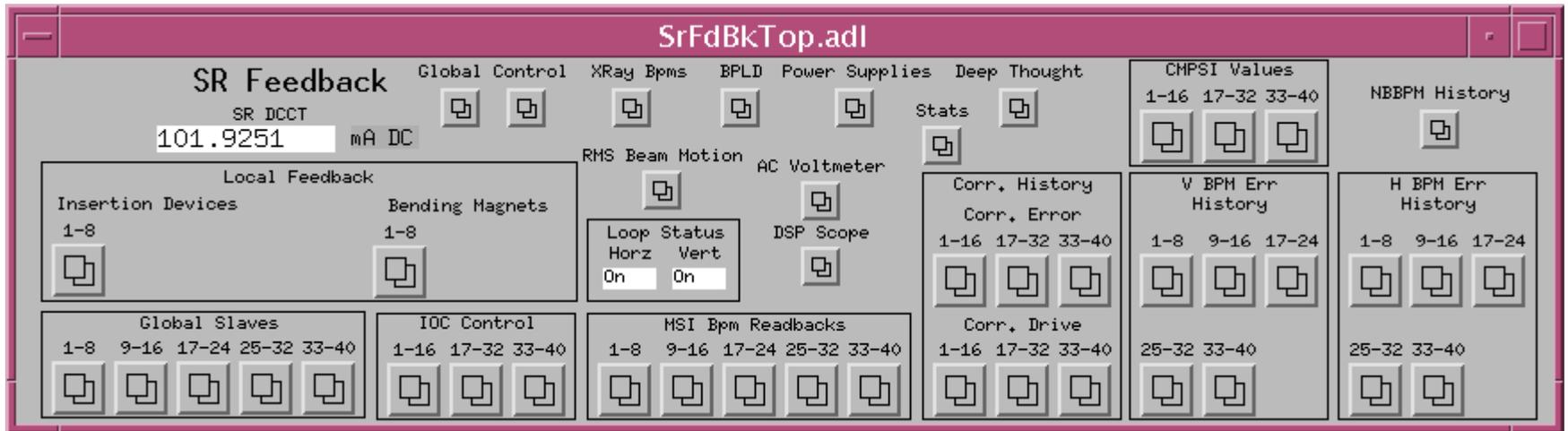


Reflective Memory Contents

- 460 X and 530 Y bpm position values
 - 280 monopulse RF BPMs
 - 150 narrow-band BPMs
 - 70 ID x-ray BPMs
 - Not all physically installed
 - 70 BM x-ray BPMs (Y only)
 - Not all physically installed
- 320 Horizontal plane and 320 Vertical plane corrector set points
 - Actually only 317 physically exist in each plane
- 160 element (per axis) bpm vector for feedback
- 160 Real-Time feedback x and y bpm set points
- Global Control Parameters
 - Sampling Rate
 - PID Gains
 - Low-Pass, High-pass filter cutoff frequency



RTFB Top Level Screen



Main Control Screen

SrFdbkGblCont.adl

Global Feedback Control

Loop Status

Horz On

Vert On

Both On

102.4307 mA

Sampling Frequency
1534.176 Hz

Loop Time
447.3 usecs

Horz FB Loop Open

Vert FB Loop Open

LP Filter Off

HP Filter Off

Gbl Sector Controls

Horz FB Loop Off

Vert FB Loop Off

Corr Mode Off

Corr Test On

Access Control

Unlimited

Maintenance

Studies

User Beam

MPS Trip Enable

RESET Disable

Heartbeat OK

Ref Mem

P0 Error OK

FB Block Enabled

Threshold 8.000 ma

IOC Message Loading parameters to DSP...

DSP Message Params written to RM

Horizontal

Low Pass Filter 2.600 Hz

High Pass Filter 0.500 Hz

Feedback Gains
Kp 28.000 Ki 0.000 Kd 0.000

Horizontal Response Matrix

File Name irm

Path /home/helios/oagData/sr/rtfeedback/lattices/default

Date Loaded Tue Jul 27 01:40:11 CDT 2010

Vertical

Low Pass Filter 25.000 Hz

High Pass Filter 0.070 Hz

Feedback Gains
Kp 0.000 Ki 0.000 Kd 0.000

Vertical Response Matrix

File Name irm

Path /home/helios/oagData/sr/rtfeedback/lattices/default

Date Loaded Tue Jul 27 01:40:11 CDT 2010

Freeze On Injection

Horz Enable

Vert Enable

Gbl Controls

AC Voltmeter

DSP Scope

Misc

Feed Forward

Modes

Connector Bpm SetPoint

Horz Vector Vector

Vert Vector Vector

Trip

Status Sector

Horz OK 39

Vert OK 8

Horz Corrector Delta Limit 10.0

Vert Corrector Delta Limit 10.0

RMS Motion Screen

SrFdbkGblRMSMotion.adl

RMS Beam Motion (Microns)

Fs **1534.176** Hz P0 Bpms
P2 Bpms
 Loop Time **526.5** usecs

IOC Message Loading DSP...
 DSP Message Loading parameters... done

Load **Stop** **Start** Processing Details

Input High Pass **0.010** Hz Low Pass #1 **30.00** Hz Low Pass #2 **100.00** Hz

	# of Bpms	Full BW	30.00Hz	100.0Hz	BPM Enables	Vs Time
x	57	4.710	0.977	3.148		
y	53	2.468	0.514	1.224		

Alarm Limits Major Alarm

	Full BW	30.00Hz	100.0Hz	microns
x	8.00	3.00	6.00	microns
y	5.00	1.50	3.00	microns

Alarm Limits Minor Alarm

	Full BW	30.00Hz	100.0Hz	microns
x	5.50	1.20	3.80	microns
y	2.80	0.65	1.40	microns

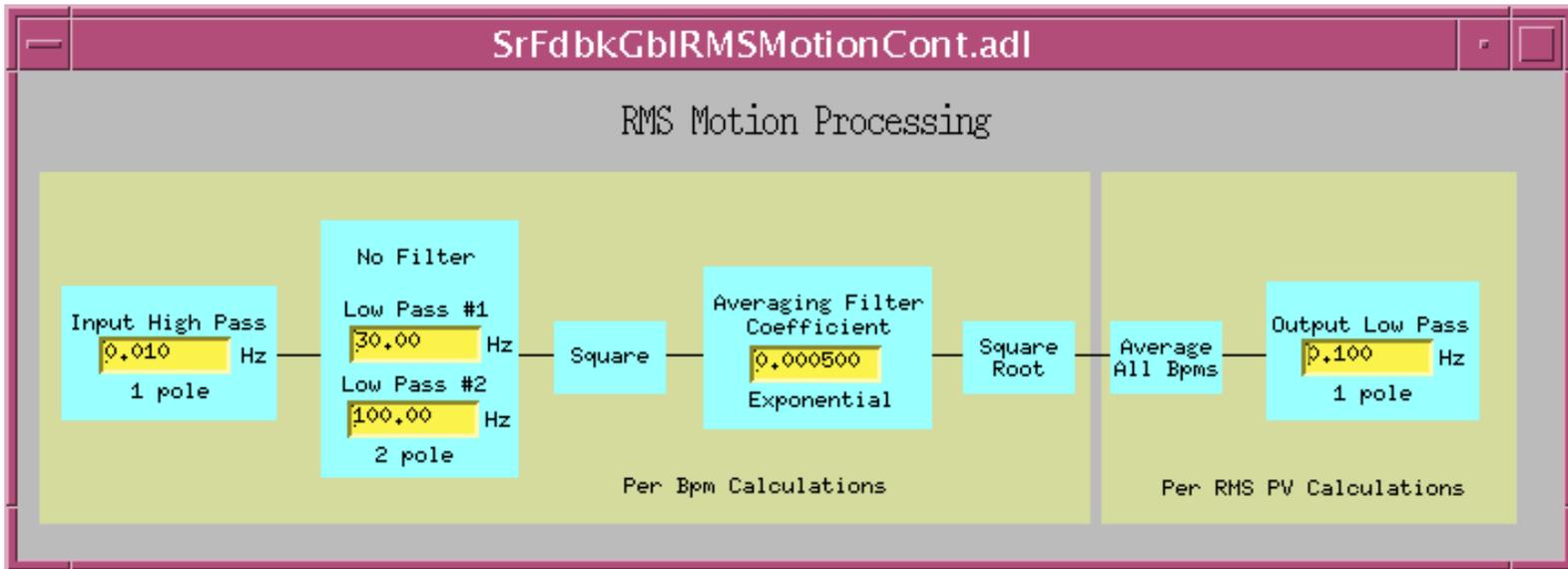
x alarm if Limit is exceeded for **3** Seconds
 y alarm if Limit is exceeded for **3** Seconds

Freeze Calculation Peak Hold Values

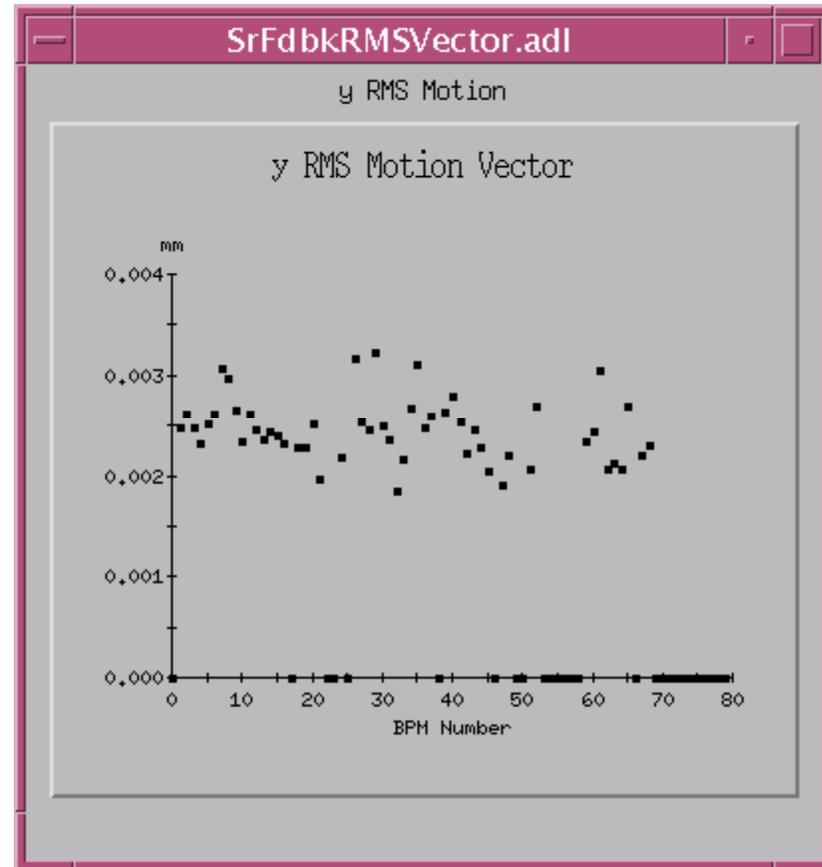
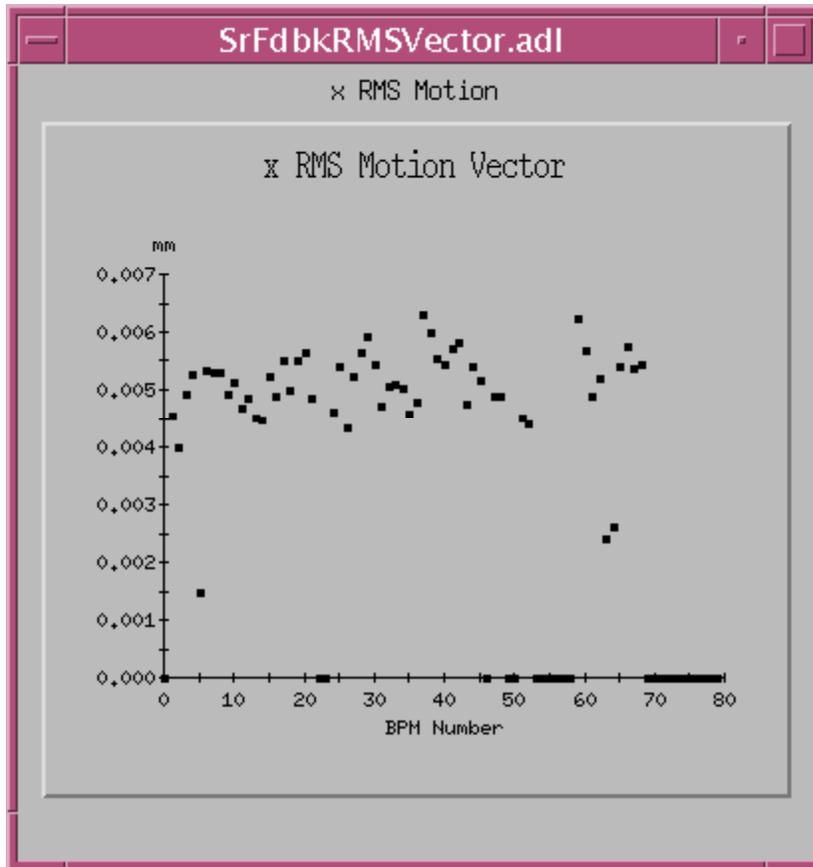
	Full BW	30.00Hz	100.0Hz	Peak Hold Time
Disable				
Enable	x 4.975	1.013	3.275	Peak Hold Time
	y 2.483	0.521	1.239	30 Secs

RMS Vectors Beta Corrected

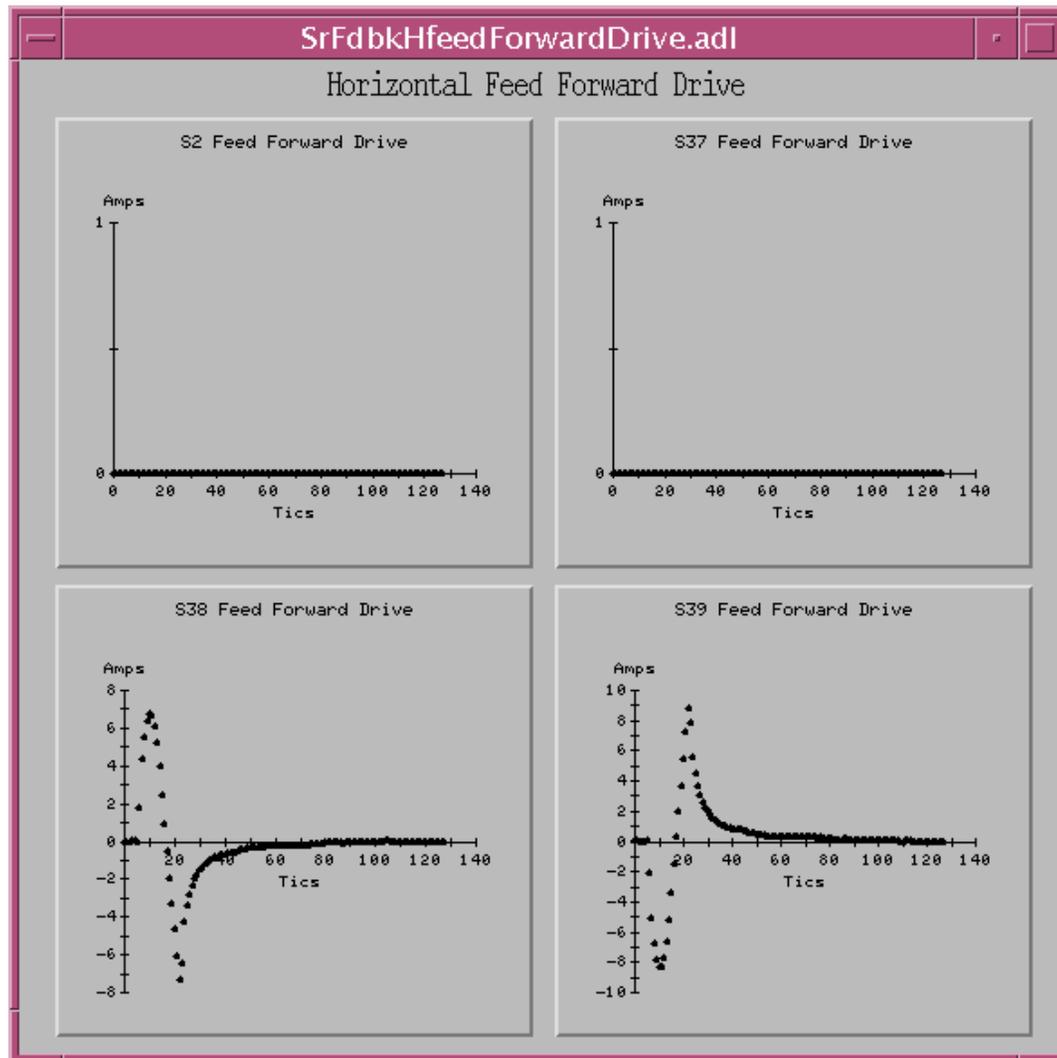
RMS Motion Calculation



RMS Motion



Feed Forward Waveforms



Corrects for
Septum Injection
Transient





RTFB Diagnostics

RTFB Node Control Screen

The screenshot shows the 'S3FB DSP Control' window with the following data and controls:

- V DSP:** Fs 1534.176 Hz, Loop Time 506.2 usecs
- H DSP:** Fs 1534.176 Hz, Loop Time 516.5 usecs
- DAS DSP:** Fs 1534.2 Hz, Loop Time 430.6 usecs
- Reflective Memory Status:** Ok
- Messages:** Loading parameters to DSP... (IOC), New Params Loaded from RM (V DSP and H DSP), Loading DSP... (DAS IOC), Loading parameters... done (DAS DSP)
- Buttons:** Reboot, Reset, Load (V DSP); Start, Stop (V DSP); Start, Stop (H DSP); Load, Stop, Start (DAS DSP); Resync, Disable, Enable (V DSP Com Port In); Disable, Enable (Com Port to V DSP); Disable, Enable (X-Blade), Disable, Enable (X-Pos), Disable, Enable (NB Bpm)

Annotations:

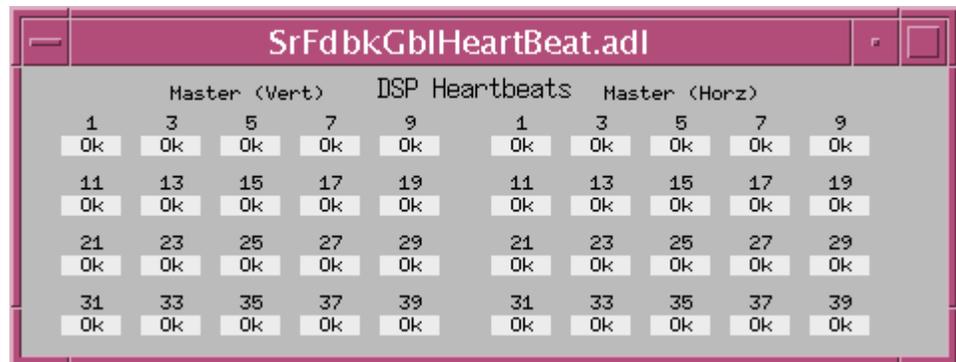
- DSP Loop Times:** A box with arrows pointing to the 'Loop Time' values for V DSP (506.2 usecs), H DSP (516.5 usecs), and DAS DSP (430.6 usecs).
- Error Messages:** A box with an arrow pointing to the 'Loading parameters... done' message in the DAS DSP section.

Feedback Iteration Clock and DSP Heartbeat Monitoring



Missing Clock Detector in Hardware

Each DSP increments a counter in Reflective Memory



Reflective Memory Monitoring

SrFdbkRefmStat.adl

SR Feedback Reflective Memory Status

Status	1	3	5	7	9	11	13	15	17	19
Node ID	20	3	19	17	16	18	5	23	15	24
	Resync									
Status	21	23	25	27	29	31	33	35	37	39
Node ID	12	10	13	14	11	4	6	9	1	0
	Resync									
Status	40	dp								
Node ID	2	25								
	Resync	Resync								

Test

RMTest.adl

Reflective Memory Write/Read Test ! Read All Test Values

	S1	S3	S5	S7	S9	S11	S13	S15	S17	S19	S21
Float	4.8161	4.8017	8.0039	2.5173	9.4003	9.2918	0.1011	8.3695	1.4263	9.6895	7.0961
Integer	0xd56f200	0xd56f200	0xd56f200	0xd56f200	0xd56f200	0xd56f200	0xd56f200	0xd56f200	0xd56f200	0xd56f200	0xd56f200
	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM
	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM
	S23	S25	S27	S29	S31	S33	S35	S37	S39	S40	DP
Float	1.0091	2.3573	9.3611	9.5171	8.1043	0.0000	4.6586	8.0064	7.0020	7.3777	7.9872
Integer	0x4f40f180	0x54281e00	0x3b085140	0x56b31380	0xe95a46	0x0	0x45821f80	0x4c979f00	0x5dd84880	0xd66af7	0x724b2780
	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM	Write RM
	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM	Read RM

Reflective Memory data flows from high to low numbered sectors
Test runs from low to high numbered sectors

Automated test

Run **Pause**

Faults since last reset **0**

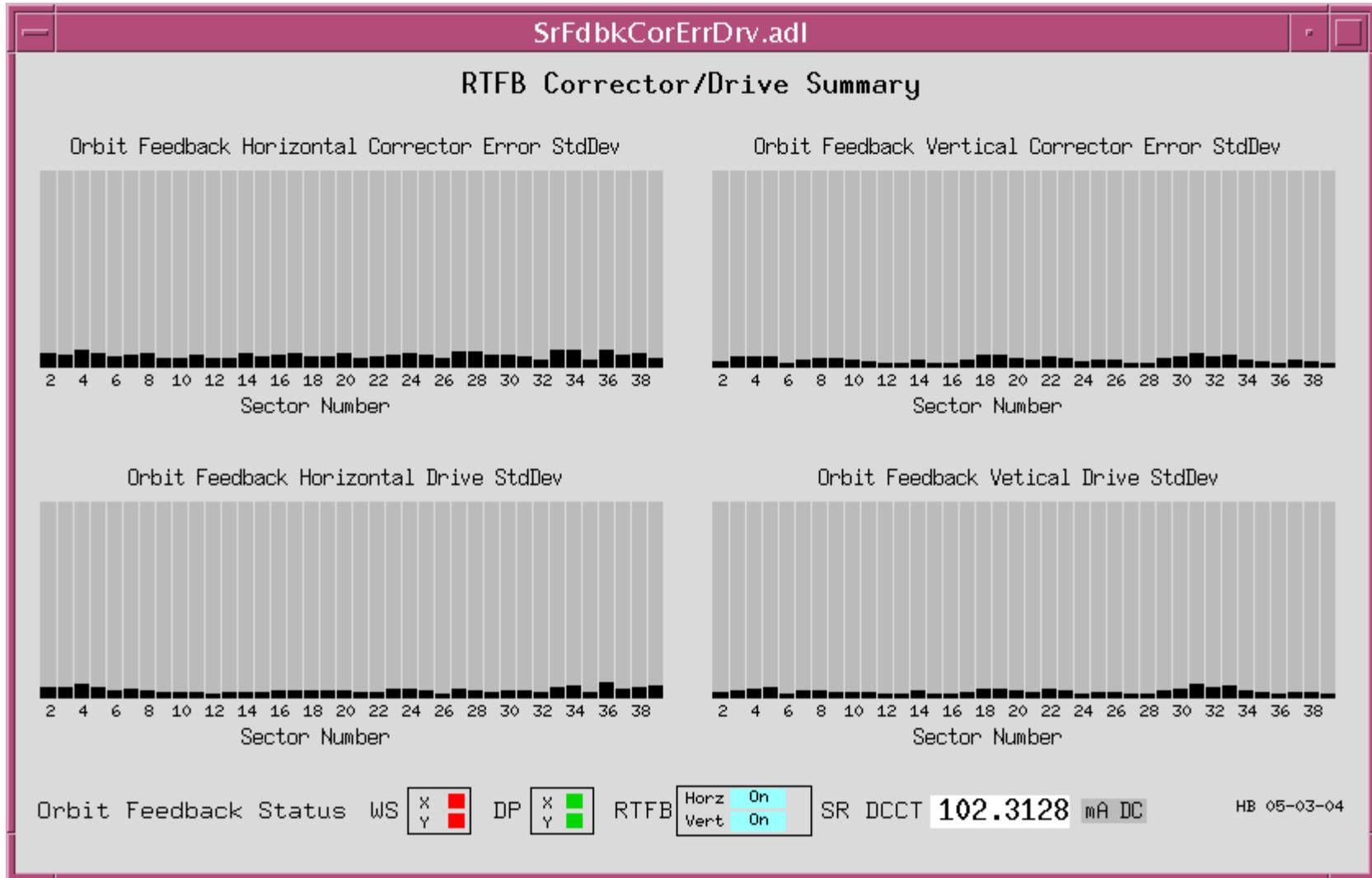
RESET

Time last reset 2010/07/30 07:07:38
Time last fault 2010/07/26 09:41:31
Last fault sector S33
Expected value 0x73992e00
Found value 0x574ccb80

Run test every **10** seconds

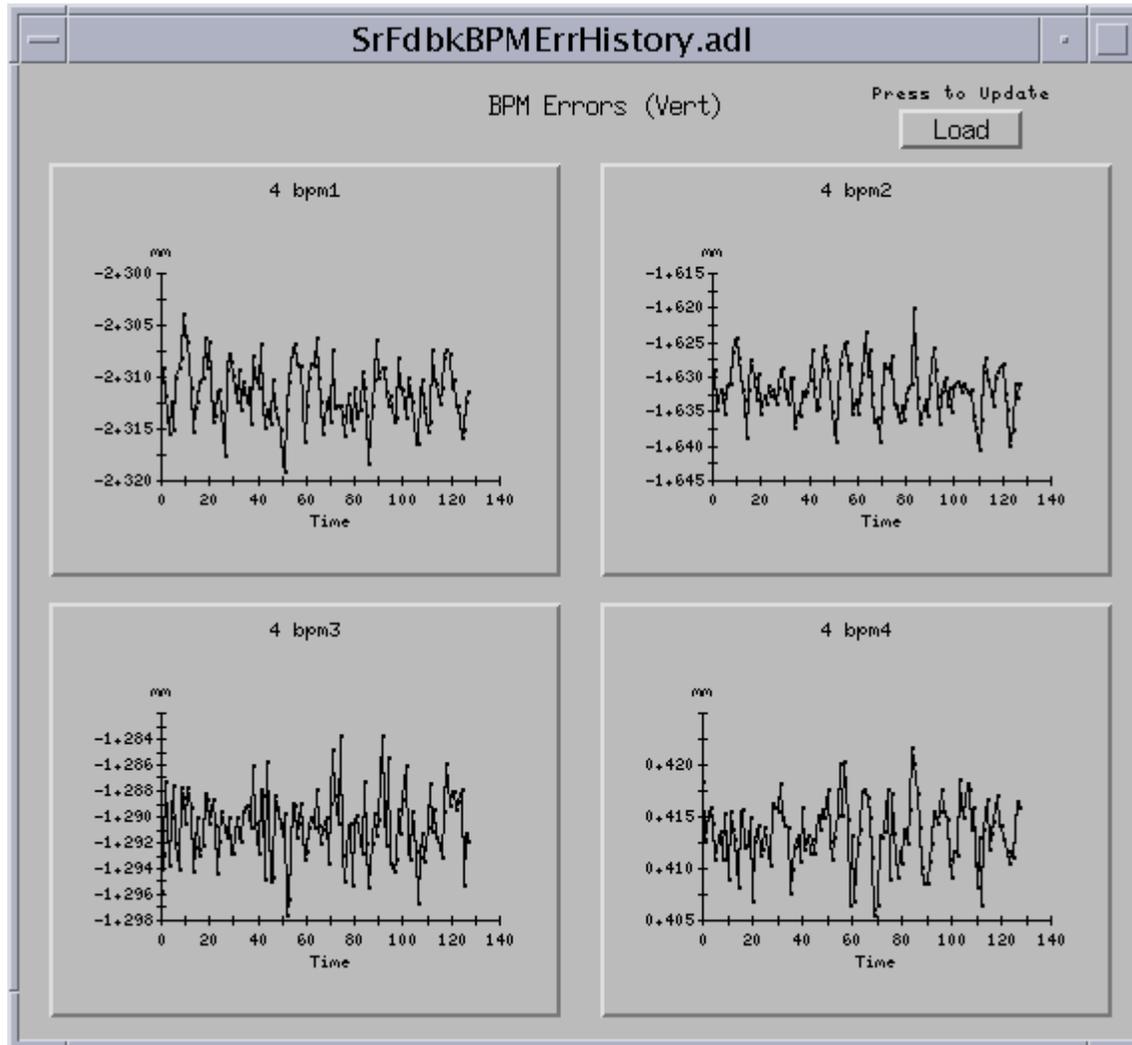
Pause on Error
Continue on Error
Test Float
Test Int
Test Both
Sleep...

Corrector Stats



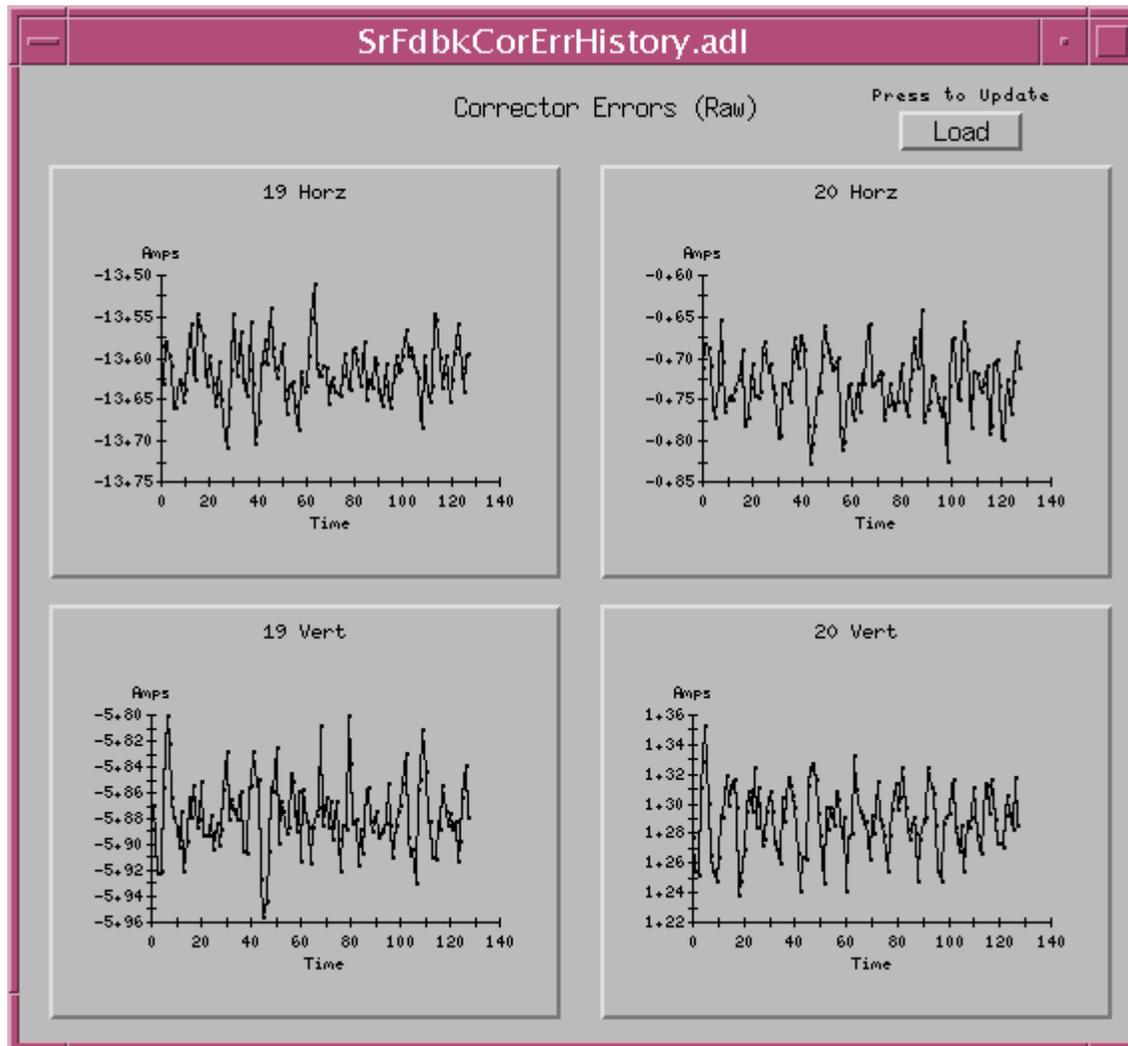
BPM Error Screen

Recorded by DSPs for each BPM used in feedback. Circular buffers hold the last 128 samples



Corrector Error Screen

Recorded by DSPs for each Corrector used in feedback. Circular buffers hold the last 128 samples



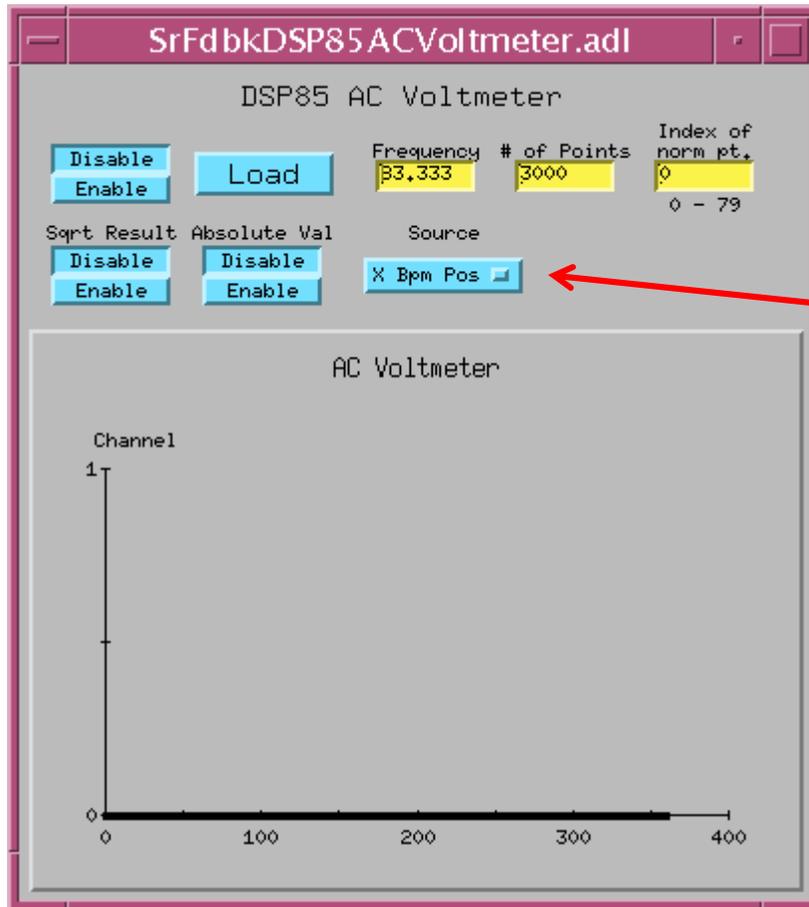
DSP Scope

- Trigger Sources**
- Freerun
 - H Loop Trip
 - V Loop Trip
 - H or V Loop Trip
 - MPS Trip
 - Any Channel
 - Injection
 - External Trigger

- Available Sources (From Reflective Memory)**
- X/Y RF Bpm Position
 - X/Y Bpm Error
 - ID X-Ray BPM X/Y Position
 - BM X-Ray BPM Y Position
 - ID/BM X-Ray BPM Blades
 - H/V Corrector Drive (Fast)
 - H/V Corrector Error



AC Voltmeter



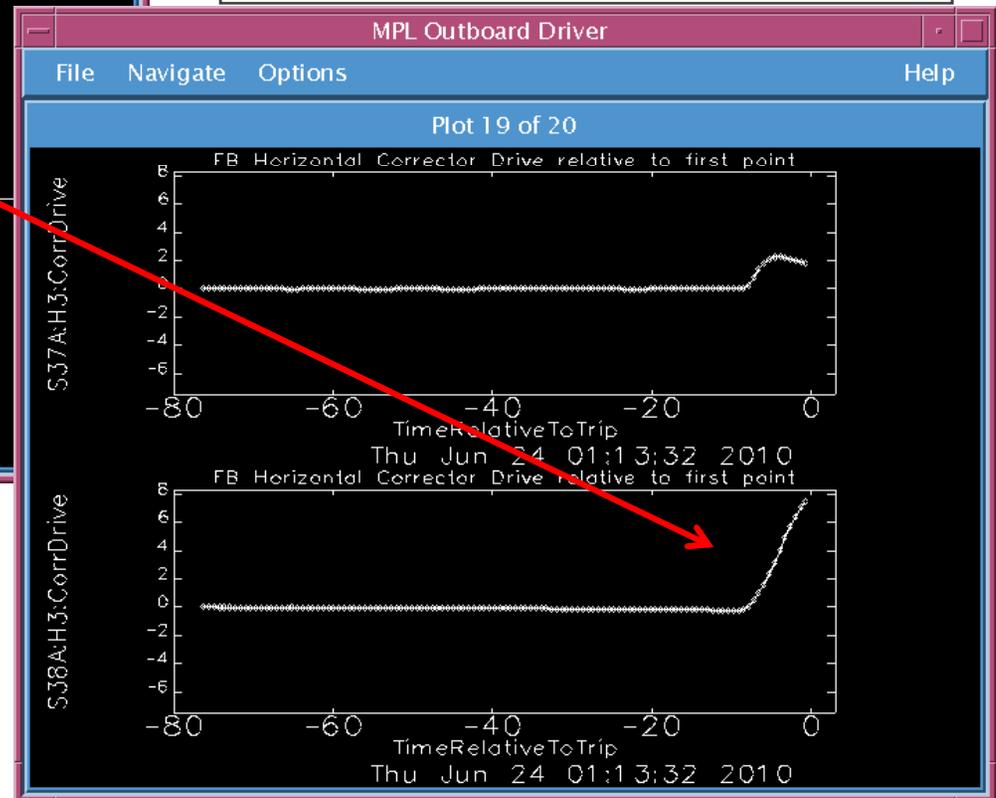
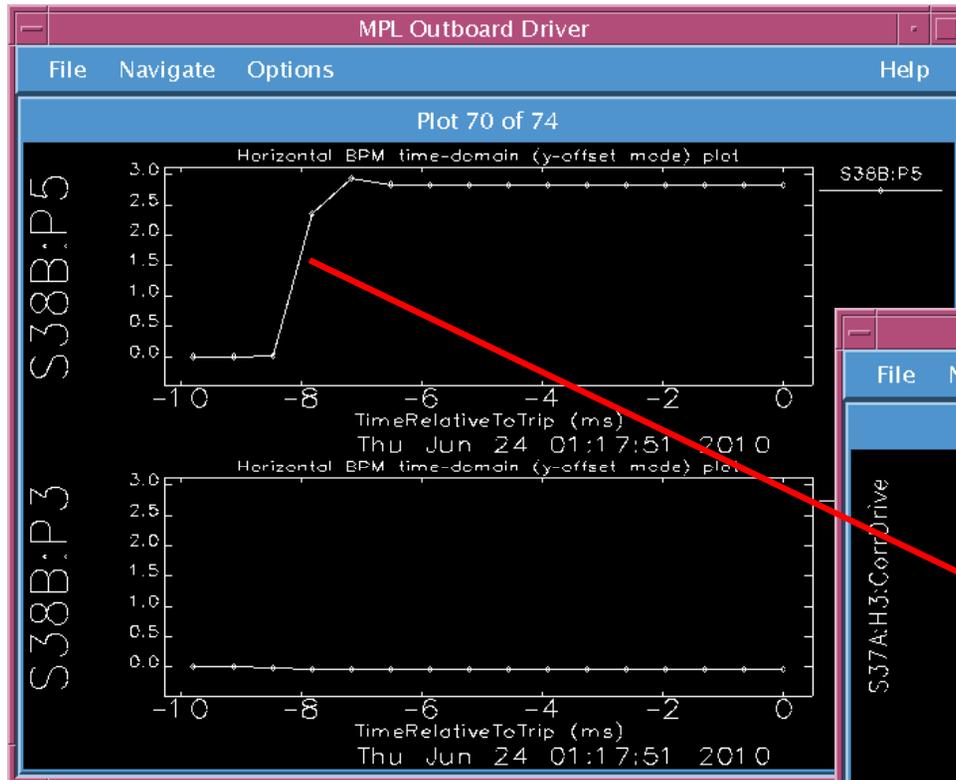
Computes FFT at a single frequency for all 360 RF BPMs

X Bpm Position
Y Bpm Position

Example Of RTFB Data Recording: Beam Loss

6/24/10

Power Supply Failed in IOC providing timing to BPM processors in S38
BPM S38B:P5 (and others in S38) jumped in position readback
This BPM was being used by RTFB
RTFB responded as witnessed by Corrector Drive
MPS tripped causing beam loss



From MPS Dump Review





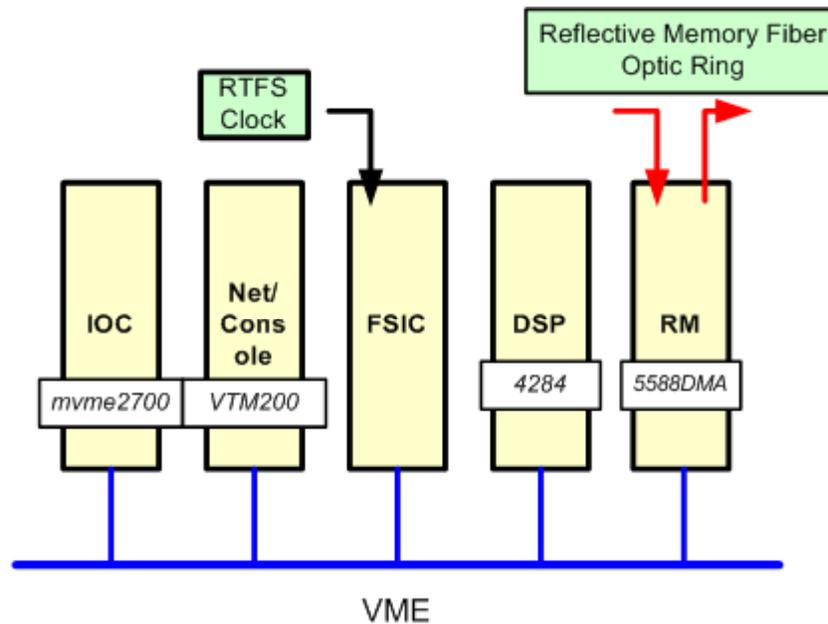
Orbit Control

Orbit Control (Datapool)

- Attaches to RTFB reflective memory ring
 - Has access to all RTFB data
 - All BPMS
 - All 640 correctors (320/plane)
- Uses SDDS tools sddsControllaw
 - Runs under vxWorks on IOC
 - Iterates at 10 Hz
- DSP performs BPM Processing
 - Digital Filtering
- Corrector vectors written to Reflective memory
 - RTFB DSPs write vectors to correctors
- Orbit control uses
 - Horizontal: Bpms – as many as possible – Correctors -2/sector
 - Vertical: Bpms – 2 or 3 per sector – Correctors – 2 or 3 /sector
- Overlap compensation
 - Minimizes “fighting” between Orbit Control and RTFB



Datapool IOC (Orbit Control)

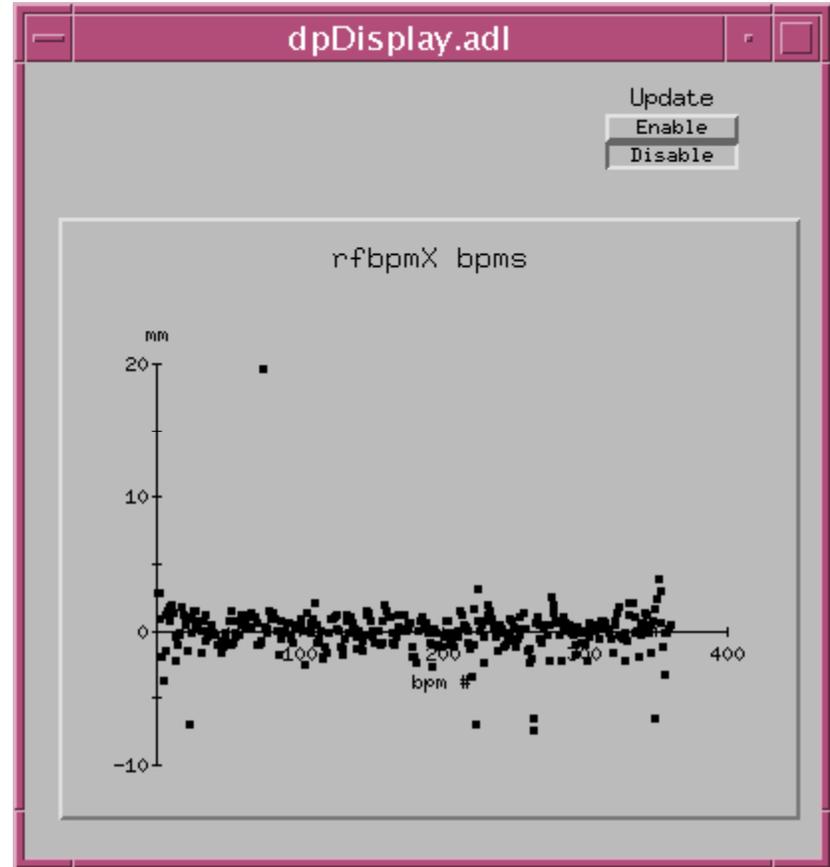
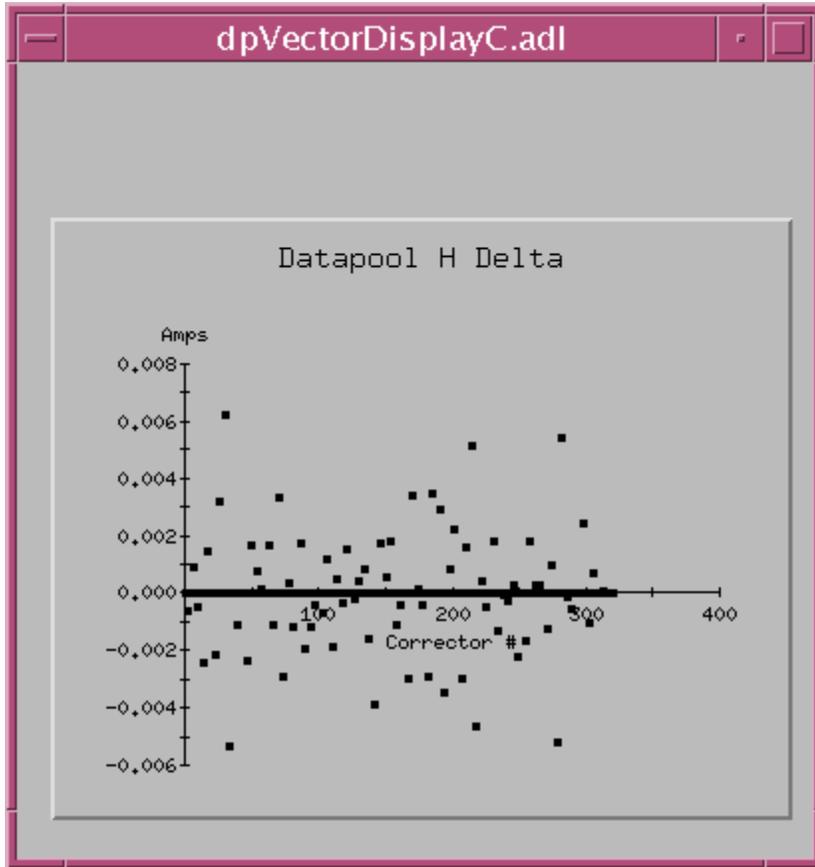


Orbit Control (Datapool ioc)

The screenshot shows the **dpCont.adl** control interface for **BPM DataPool DSP Control**. Key components include:

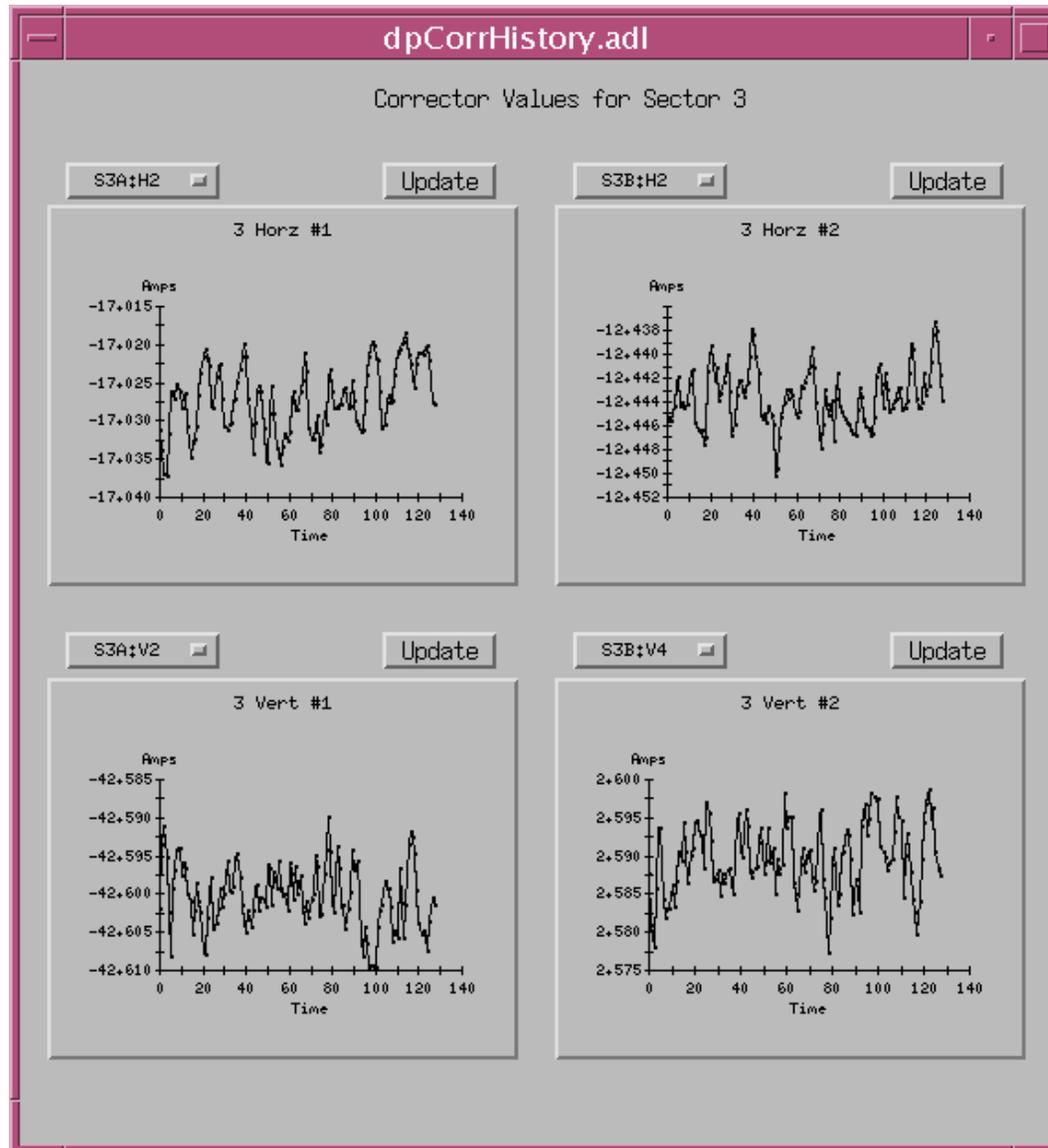
- System Status:** CPU Load (26.83%), Fs (1534.2 Hz), Loop Time (1858.0 usecs), and IO/DSP Messages.
- Processing Controls:** Buttons for **Load**, **Stop/Start**, and **Linear/Polynomial** processing modes.
- Reflective Memory:** Status (Ok), Node ID (25), and **Resync** button.
- Correction and Setpoint Management:** Panels for **Corrector Vectors to RM** (Vertical/Horizontal) and **BPM SetPoint Vectors to RM** (Y/X), each with **Disable/Enable**, **Scalar/Vector**, **Write**, and **Reload** options.
- Advanced Settings:** **Lowpass Filter** (10.0 Hz), **Decimate Factor** (15), **MPS Trip** (0), and **Test Status** (H Plane/V Plane 0.0).
- History:** A **History** section with **TimeStamps** (1-8, 9-16, 17-24, 25-32, 33-40) and corresponding data icons.
- Instructions:** **Write:** Loads Changed values into reflective memory. **Reload:** Loads all values into reflective memory. Does not write to CMPSI.

Datapool Live Displays



Datapool Data Recording

Records Last
128 values for
all correctors.





APS Up Grade

- RTFB will be upgraded as part of Orbit Stability improvement

APS-Upgrade Beam Stability

		AC Motion (0.1-200 Hz)		Long term (1 week, pk-pk)	
Horizontal	Now	5.0 μm	0.85 μrad	7.0 μm	1.4 μrad
	Upgrade	3.0 μm	0.5 μrad	5.0 μm	1.0 μrad
Vertical	Now	1.6 μm	0.8 μrad	5.0 μm	2.5 μrad
	Upgrade	0.4 μm	0.2 μrad	1.0 μm	0.5 μrad

M. Borland et al., SPX Technical Study 7/27/10

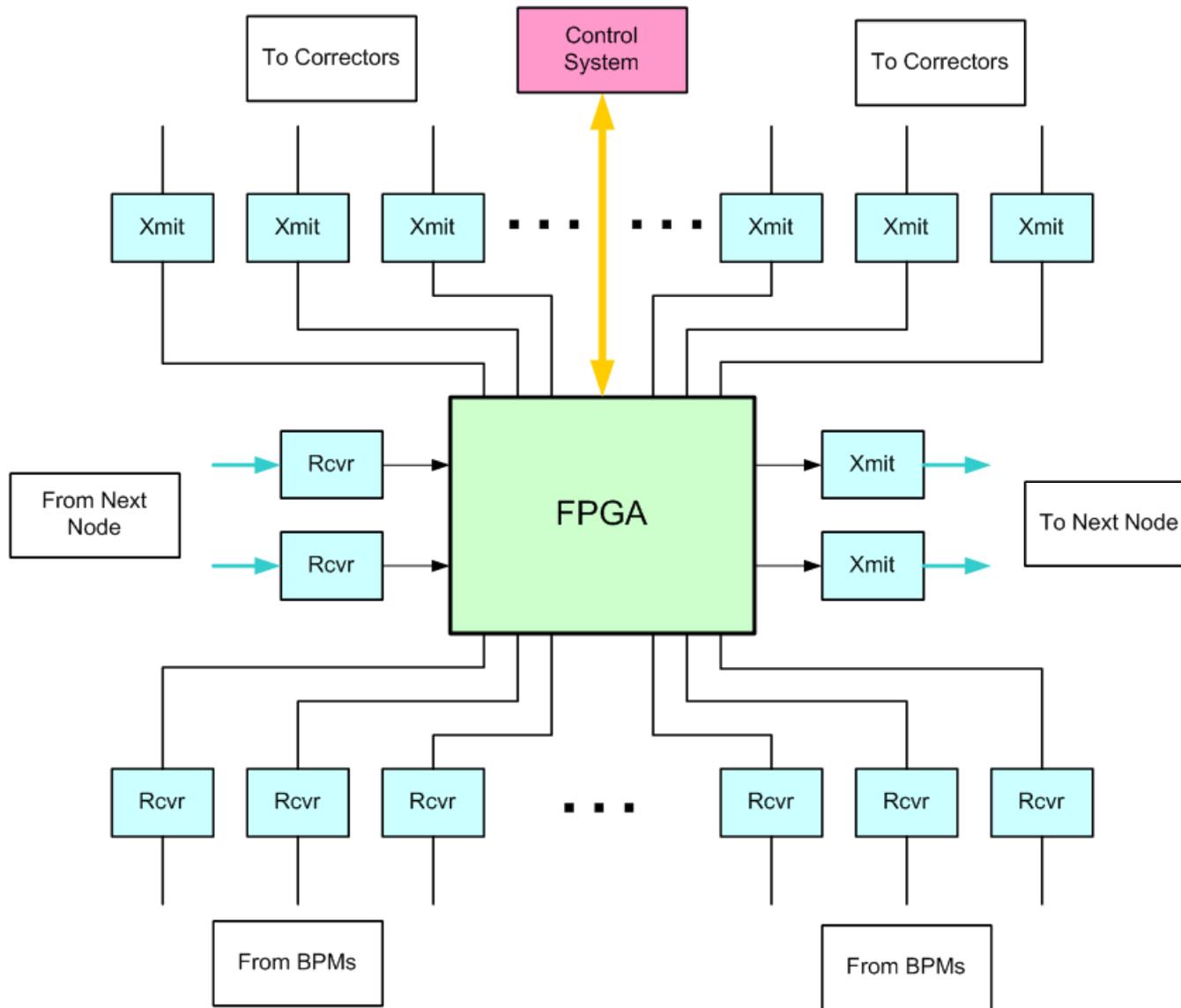


Upgrade to RTFB

- Sample Rate increased to 20 kHz
- Correction Bandwidth extended to 200 Hz
- 8 BPMs per axis per sector
 - 320 BPMs per axis total
- Two correctors per axis per sector
 - Not all sectors will have two fast correctors
- Algorithm to be implemented in FPGAs



RTFB Upgrade Concept





The End
Thank you